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ABSTRACT

Implications of two studies conducted by the Institute for Human and Machine Cognition (IHMC) at the University of West Florida (Pensacola) regarding electrophysiological determinants of cognitive style (CS) are discussed. Most of the IHMC's research focuses on bimodal processing theory, according to which the human brain has at least two qualitatively different modes of thought: the analytic mode, which is logical, linear, and sequential and the holistic mode, which is simultaneous, parallel, or gestalt. The first study, conducted by B. R. Dunn and others in 1981, involved the use of expository texts that had a hierarchically organized logical semantic structure. The second study, conducted by B. R. Dunn and M. D. Reddix in 1984, involved having subjects read one highly holistic poem and one logical or analytical poem. Recordings of ongoing electroencephalographic (EEG) activity have been used at the IHMC to study global aspects of complex cognitive processes underlying the reading and encoding of connected discourse. EEG activity in the alpha bandwidth (8 to 13 Hertz) is a reliable correlate of a person's modal processing or CS, not merely a measure of mental alertness. Study results indicate that while a person reads exposition, the right hemisphere functions to a greater extent than the left; the opposite is true while a person reads poetry. For expository texts using tight cause and effect relations, subjects classified as analytics recall more superordinate or gist information than those classified as holistics. For males, bimodal theory predicts their recall pattern for both prose and poetry quite well. In contrast, bimodal theory predicts female recall only when the text is in a logically structured expository form. There seem to be real gender differences in cognitive processes. Differential brain organization may lead to (possibly qualitative) differences in CS. It is suggested that if such qualitative differences exist, a universal instructional approach applied to all students may not be appropriate. A 31-item list of references, 2 data tables, and 5 figures are included. (TJH)

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ELECTROPHYSIOLOGICAL DETERMINANTS OF COGNITIVE STYLE: IMPLICATIONS FOR EDUCATIONAL AND PSYCHOLOGICAL RESEARCH

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Electrophysiological Determinants of Cognitive Style:
Implications for Educational and Psychological Research

In this presentation I will briefly describe the general points of 10 years of research from our laboratory (e.g., Dunn, Gould, & Singer, 1982; Reddix & Dunn, 1984; Raney & Dunn, 1989) which we believe has demonstrated that recordings of ongoing electroencephalographic (EEG) activity can be used to study global aspects of complex cognitive processes underlying the reading and encoding of connected discourse. More importantly, we will attempt to demonstrate that EEG activity in the alpha bandwidth (8-13 Hz) is a reliable correlate of a person's modal processing or cognitive style. That is, alpha is not merely a measure of mental alertness as proposed by Anderson & Anderson (1968).

Our experimental approach has yielded three general findings of interest (Reddix & Dunn, 1988) First, our data support the notion that a person's general or global processing strategy (which we call a person's modal processing style) can account for significant individual differences in the encoding and recall of expository text and poetry (e.g., Hymes, Dunn, & Gould, 1977; Dunn, Gould & Singer, 1981; Reddix & Dunn, 1984; Second, a person's modal processing style can be identified and monitored using scalp recorded electroencephalographic (EEG) activity (Deikman, 1971; Doktor & Bloom, 1977; Dunn et al. 1981; Reddix & Dunn, 1984; Hymes et al., 1977. Third, hemispheric dominance for language processing (especially reading) may be an overly simplistic way to think about the dynamic aspects of text processing, encoding, and individual differences, while masking the whole brain's complex involvement in language processing (see Dunn, 1985a, 1985b for reviews). Demonstration of these points provides an important platform for theoretical and empirical investigations of individual differences in cognitive processing, thus substantiating the claim that electrophysiological measures have important educational implications (Reddix & Dunn, 1988).

Bimodal Theory

Most of our early research was based on bimodal processing theory. According to bimodal theory, the human brain has at least two qualitatively different modes of thought: the analytic mode which is a logical, linear, and sequential processing system and the holistic mode which is a simultaneous, parallel, or gestalt processing system. Note, again, that these modes are not a function of simple left vs. right hemisphere dependency (see above). They are, in our view, caused by dynamic and differential interactions of various brain systems.[1]

Although every person utilizes these two modes, some people typically use one more than the other (Deikman, 1976; Dunn, 1985a; Hymes, Dunn, & Gould, 1977). Thus, it is possible for one person to be predominantly analytical in processing style and another to

be more holistic. An extreme analytic would be one who would prefer a logical, methodological approach to problem solving and text comprehension. An extreme holistic, in contrast, would be one who relies more on intuition than logic in performing these tasks. Hence, an analytical person would tend to process text in a logical (or hierarchical), sequential manner; whereas, an extreme holistic would tend to use more paralogical or gestalt processing.

Further, our data as well as that of others (e.g., Deikman, 1971, 1976; Hymes, Dunn, & Gould, 1977; Dunn, 1985a) support the notion that the two modes can be determined by EEG patterns. Specifically, when people are in the holistic mode, they tend to be relaxed and produce an abundance of alpha (8-13 Hz) activity. When people are in the analytic state, they are more alert and produce less alpha activity (Deikman, 1971; Dunn, 1985a). More specifically we have predicted that people who are predominantly analytical in their processing style will learn more in a high state of arousal and consistently will produce less alpha than holistics. In contrast to holistics' best performance will occur when they are in a relaxed state and when they are producing relatively high levels of alpha(Deikman, 1971; Dunn, 1985).

At this point, I would like to briefly describe two of several of our studies which have used expository and poetic text as stimuli, both of which are particularly germane to this symposium concerning psychophysiological correlates of reading and all of which support our notions of modal processing style I have briefly described above.

In all of our early work, a person's processing style (analytic or holistic) was determined based on the amount of alpha activity (8-13 Hz) produced during a 5 to 10 minute eyes-open baseline. All subjects' alpha data were then rank ordered. Those subjects who produced less than median alpha were termed analytic. Those producing greater than median alpha where called holistic. All recordings were made over Wernicke's area on the left hemisphere and its homologous site on the right-hemisphere. In our first study (Dunn, Gould, & Singer, 1982), Cz served as the primarily reference electrode. In the second study (Reddix & Dunn, 1984) both Cz and linked ears were used and were compared.

Dunn, Gould, & Singer, 1981

In our first "reading" related study (Dunn, Gould, & Singer, 1981), we used expository text which had a hierarchically organized, logical semantic structure. The semantic or logical structure was identified using Bonnie Meyer's (1975) text-analysis system. The passage itself was broken into eight segments and placed on individual slides and EEG was recorded during the reading of each slide. Each text-segment contained information ranging from highly important "gist" (or level 1) information to lower-level (level 5), detail information. Half the subjects were instructed to relax during learning while the other half were instructed to be alert and to concentrate as much as possible

during learning.

When the proportional recall data were analyzed, the highly important 3-way (type of processor x instructions x level of text information) interaction was found to be significant and is shown in Table 1.

Insert Table 1 about here

From Table 1 it can be seen that analytics best recall occurs when asked to learn when given concentration instructions and their recall follows the typically found logical pattern of hierarchical recall found by Meyer (1975) and others (Meyer, Brandt, & Bluth, 1980). Holistics best "gist" (L1) occurred when they were given relaxation instructions and the pattern of recall did not follow the typical hierarchical pattern of the analytics, particularly when they were given concentration instructions.

Insert Table 2 about here

Table 2 shows the alpha activity generated during the encoding of the entire text. It is clear from the table that analytics always produced less alpha than holistics during the reading task, and that the left and not the right hemisphere produced the most alpha during reading. This latter finding dealing with alpha activity appears not to be an anomaly as other, independent researchers have obtained similar findings when narrative text is encoded (e.g., Kraft, Mitchell, Languis, & Wheatley, 1980).

The findings of our first text study support our version of bimodal theory in three ways: First they showed that EEG activity in the alpha bandwidth can be used to identify persons having an analytical vs. at least an "less" analytical or possibly even a holistic cognitive style. Secondly, it appears that the use of relaxation and alert instructions can differentially shift the modal balance used by subjects. Third, it shows that the simplistic view that the left-hemisphere is the primary hemisphere for text encoding is an oversimplification.

You will note, that up to this point, only one extreme of the modal cognitive style continuum had been tested by us. That is, all subjects in both our word-list (Hymes, Dunn, & Gould, 1977) and expository text experiments (Dunn, Gould, & Singer, 1981) were given material with either an implicit or explicit logical organization. This favored analytic processors who, according to theory, should excel at learning this type of material. In fact, we ourselves have argued (Dunn, 1985a, Dunn et al., 1981) that those termed "holistics" may merely consist of less able students lacking in reading ability. [The relation between modal processing

style and reading ability is doubtful, however. In a study not reported here (Rust, 1982, cited in Dunn, 1985a, and reanalyzed by Raney & Dunn, 1989), a small and insignificant correlation ($r(19)= -.25$, $p > .25$.) was found between subject's reading ability (as determined by the Comprehensive Test of Basic Skills) and processing style (as determined by eyes-open, alpha (EEG) baseline, measurements].

Consequently, we argued that if bimodal theory is correct, then extreme holistics should recall relatively more information from text that reflects their intuitive or gestalt-like processing style, namely non-logically structured poetry. We then ran an experiment to test these notions (Reddix, 1983; Reddix & Dunn, 1984).

Reddix & Dunn, 1984

Participants read two poetry selections. One poem was judged as highly holistic, whereas the other was judged as more logical or analytical by eight independent raters (see Reddix & Dunn, 1984 for details). Neither poetry selection contained rhyme sequences. Experimental poetry passages were reproduced on 35mm slides (one stanza/slide).

Electrophysiological recordings were made during the reading of each stanza from two parietal temporal sites; i.e., from a point midway between P3 and T3 on the left hemisphere, and midway between P4 and T4 on the right, in accordance with the 10-20 Electrode System (Jasper, 1958). This allowed for observations of differential hemisphere activation. Recording sites were referenced to Cz yielding two bipolar recordings. A linked-ears reference was also used, allowing for the comparison of bipolar and monopolar recording techniques, the differences between which are not important here.

Following our past research (Dunn et al, 1981; Hymes et al., 1977) subjects were dichotomized into analytic and holistic processors based on their average bilateral alpha activity produced during a five minute eyes-open baseline period. Subjects average alpha was rank ordered and those whose alpha was below the median were designated as analytics. Those whose alpha scores were above the median were categorized as holistics.

Proportional metaphor recall protocols were analyzed separately using a four-way mixed analysis of variance. The independent variables were cognitive style, gender, poem, and level (level of metaphoric relationship in the content structure of the poem). Poem and level were repeated measures. Data analyses utilized arcsine transformation, however, the reader should note that non-transformed data yielded equivalent significant results.

When the recall data were analyzed the important three-way interaction of poem by cognitive style by gender was found to be significant and is shown in Figure 1 as two 2-way components for

ease of discussion. It should be noted that the differential recall pattern of males and females, suggests a possible gender difference in modal processing.

Insert Figure 1 about here

Male holistics, in accordance to theory, were able to recall the higher-order structure or gist of the poem whereas male analytics were not. However, just the opposite occurred with the female subjects. It was the female analytics who recalled the gist and female holistics who could not.

Our alpha data, collected on-line during the reading of the poetry (especially the relative alpha data at both Cz and linked ears) also support possible gender differences. With both sets of data, a significant three-way, gender by hemisphere by reading slide, and a significant four-way, cognitive style by gender by poem by slide interaction was obtained. The data were at best messy and at worst uninterpretable! Consequently, for descriptive purposes only, Figures 2 and 3 show these data collapsed across slide, reducing them to two- and three-way interactions respectively.

Insert Figures 2 & 3 about here

Three interesting observations emerge from these data. First, it appears that males were primarily responsible for the hemispheric differences in alpha (see Figure 2). Second, in contrast to our previous work (Dunn et al., 1981) which showed that all subjects (both analytic and holistic) produced more alpha in their left hemispheres during the reading of expository text, the present data using poetry, indicate that most subjects produced more alpha in their right hemisphere (Figure 2). Third, holistics produced more mean alpha than did analytics (Figure 3), thus supporting our previous work using expository text (e.g., Dunn et al., 1981).

Summary and Educational Implications

Taken together, the results of our two studies suggest that while reading exposition the right hemisphere is relatively more engaged than the left hemisphere (similar findings have been obtained by Kraft, Mitchell, Languis, & Wheatly, 1980 and were reported earlier). The opposite occurs when subjects read abstract poetry. In any case, different text appears to require differential cerebral activation.

Further, when expository text is structured using tight cause and effect relations (Breeder Reactor passage, Dunn et al., 1981) both male and female analytics recall more superordinate or gist information than either male or female holistics. However, as prose shifts to a highly abstract or holistic vein (descriptive poetry, Reddix, 1983; Reddix & Dunn, 1984) a gender by style interaction occurs. Males again follow the pattern predicted by bimodal theory, i.e., male holistics recall the gist, male analytics do not.

For males, bimodal theory predicts their recall pattern for both types of text quite well. In contrast, bimodal theory predicts female recall only when the text is logically structured and is in expository form. That is, both female analytics and holistics recalled the gist of the "holistic" poem at approximately the same relatively low rate (.13 vs .15, respectively) and female holistics tended to recall proportionally more of the logical poem than did female analytics (.19 vs .10, respectively), although these differences were not statistically significant using conservative Scheffe's post-hoc tests.

What are we to make of this interaction of gender and style with "holistic text"? Given the correlative brain activity data we have reported, there is prima facie evidence for "real" gender differences in cognitive processing. The work of Sandra McGlone (1980) and Jere Levy (1980) suggests these apparent gender differences may be due, in part, to differences in the within-hemisphere organization of the two sexes.

Although these gender differences are an interesting topic for future research, the point we would like to stress (as we have several times before e.g., Dunn, 1985b) is that differential brain organization may lead to differences--possibly qualitative differences--in cognitive style, similar to the analytic and holistic styles we have reported. If such qualitative differences exist, we believe that a universal instructional approach applied to all students may not be appropriate.

In fact, since we also believe that all people have both analytic and holistic capabilities to some degree, we would like to argue that every student should be taught, that in most cases, there are several strategies that can be used (separately or in combination) to solve most problems in school (including mathematics). Consequently, since we also think that the brain's metacontrol or executive system is most adaptive when it has numerous strategies at its disposal, like analytic and holistic strategies, teaching strategic knowledge and cognitive flexibility should be stressed to all students in our schools (Dunn, 1985b, Reddix & Dunn, 1988).

Future Directions

Although we have been able to reliably identify two extreme cognitive styles using EEG alpha measurements (i.e., analytic and

holistic), we do not want to leave the impression that we believe analytics and holistics are extreme styles on a single continuum. They should not be viewed as a dichotomy. Figure 4 shows that we believe any person's cognitive style is based, in part, on different mixtures of analytic and holistic thought.

Insert Figure 4 about here

Consequently, a high analytic is someone who has an excess of analytical skills relative to their holistic ability. We are very aware, as also can be seem from Figure 4, that some people are well versed at both types of processing (in the experiment just presented female analytics would fall into this category) whereas others are not. Most of us probably cluster somewhere around the middle of the figure.

Based on these assumptions, our future research will be focused on identifying people in the outlying areas of the four quadrants whose mixture is unique enough to be considered a separate cognitive style. A promising method for identifying different cognitive styles in these quadrants is the use topographic mapping of the brain's electrical activity while subjects are engaged in various cognitive tasks like reading text. Figure 5 shows the differential cortical patterns of 10 Hz

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Insert Figure 5 about here

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activity (in the middle of the 8-12 Hz alpha range) generated by two analytics and two holistics. It is our hope that these differential cortical patterns will allow us eventually to identify persons having styles similar to those contained in the four quadrants above.

ENDNOTE

1 Bimodal Theory

Our theoretical basis for postulating modal processing styles is somewhat eclectic, and will require a brief review of relevant research in order to establish modal style (again which we define as a general processing strategy) as a fundamental aspect of cognition worthy of empirical investigation. In brief, we believe that the neurocognitive research indicates: 1) that the whole brain is used during complex tasks (Dunn 1985a, 1985b). In fact, several recent models have been postulated to account for the apparent interactive nature of the brain's cerebral hemispheres (Das, Kirby, & Jarman, 1975; Goldberg & Costa, 1981; Levy & Trevarthen, 1976; Luria, 1973). 2) the brain's hypothesized metacontrol (Levy & Trevarthen, 1976) or executive system may use different strategies to differentially engage the cerebral hemispheres to perform certain tasks (as suggested by the literature on hemispheric switching when the same stimuli are processed under different instructions - see Bryden, 1982 for a review). Such hemispheric switching has occurred in visual half-field studies (e.g., Cohen, 1972; Geffen, Bradshaw, & Nettleton, 1972; Segalowitz & Stewart,1979), dichotic listening research findings (e.g., Spellacy & Blumstein, 1970) and studies using frequency measurements as the dependent variables (Ornstein, Johnstone, Herron, & Swencionis (1980). Taken together, we believe that these studies have demonstrated that a person's <u>processing strategy</u> as opposed to the experimental tasks <u>per se</u>, may be responsible for reversing hemisphere laterality effects. In our opinion these strategies are regulated by the metacontrol system; and 3) people may vary in the way their brain is organized, and that these "unequal patterns" of organization, account, in part, for cognitive style differences (Dunn, 1985a, 1985b; Kraft, 1981, 1983, 1985; Languis & Naour, 1985; Levy, 1980).

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TABLE 1
Mean Proportional Semantic Recall of a Function of Type of Processor, Instructions and Levels in the Context-Structure, Scored Using Meyer's Procedure

Type of Processor	n	Levels in Content Structure 1	2	3	4
Analyticals					
Concentration Instructions	9	.67	.28	.24	.17
Relaxation Instructions	11	.52	.29	.22	.23
Holistics					
Concentration Instructions	11	.39	.33	.24	.23
Relaxation Instructions	9	.49	.20	.08	.09

TABLE 2
Mean Alpha Power Recorded During Reading as a Function of type of Processor and Hemisphere

Type of Processor	Hemisphere	
	Left	Right
Analytic	.73	.46
Holistic	1.98	1.45

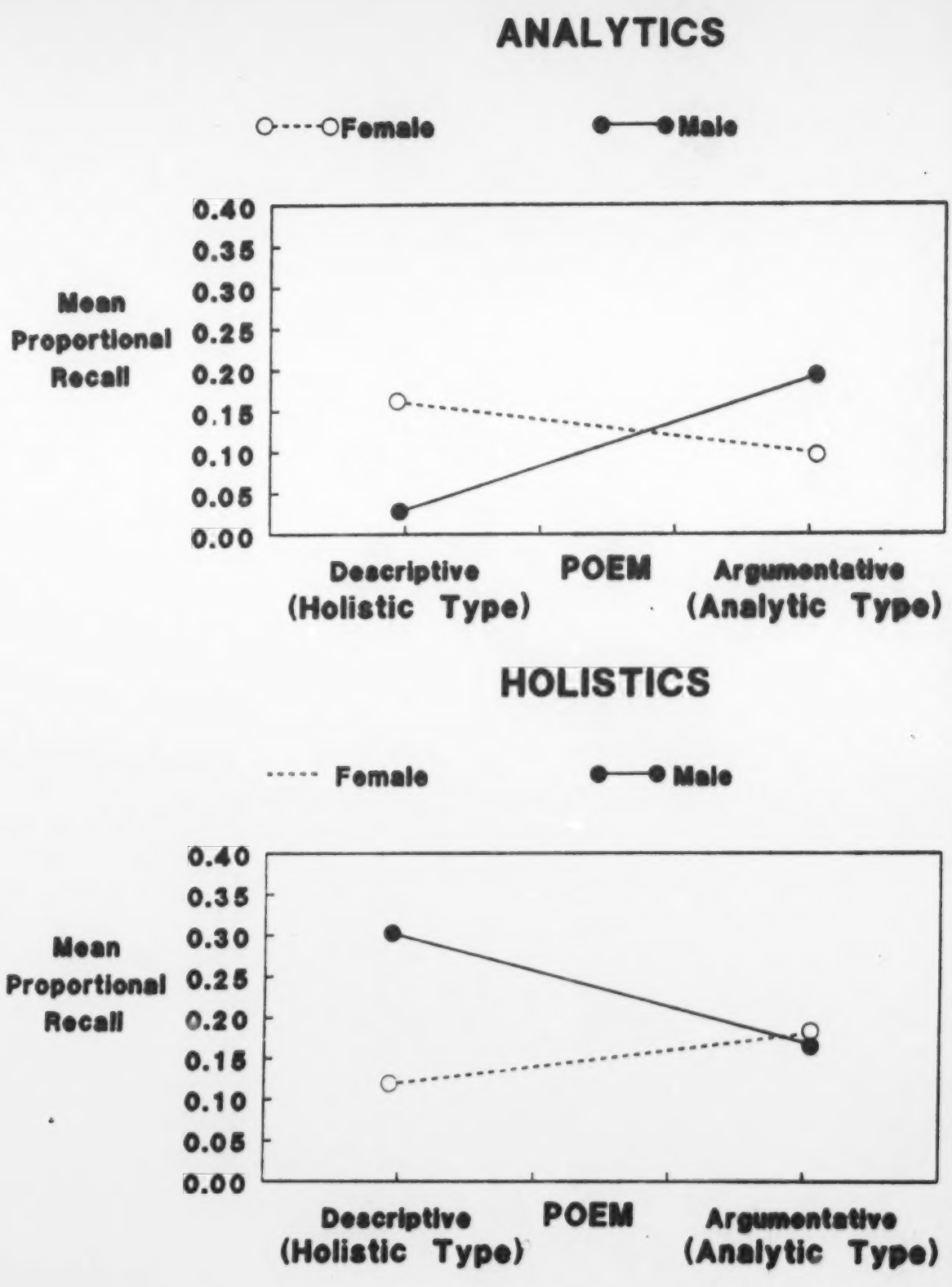


Figure 1 Mean proportional "Gist" Recall as a function of type of Processor, Gender and Poem.

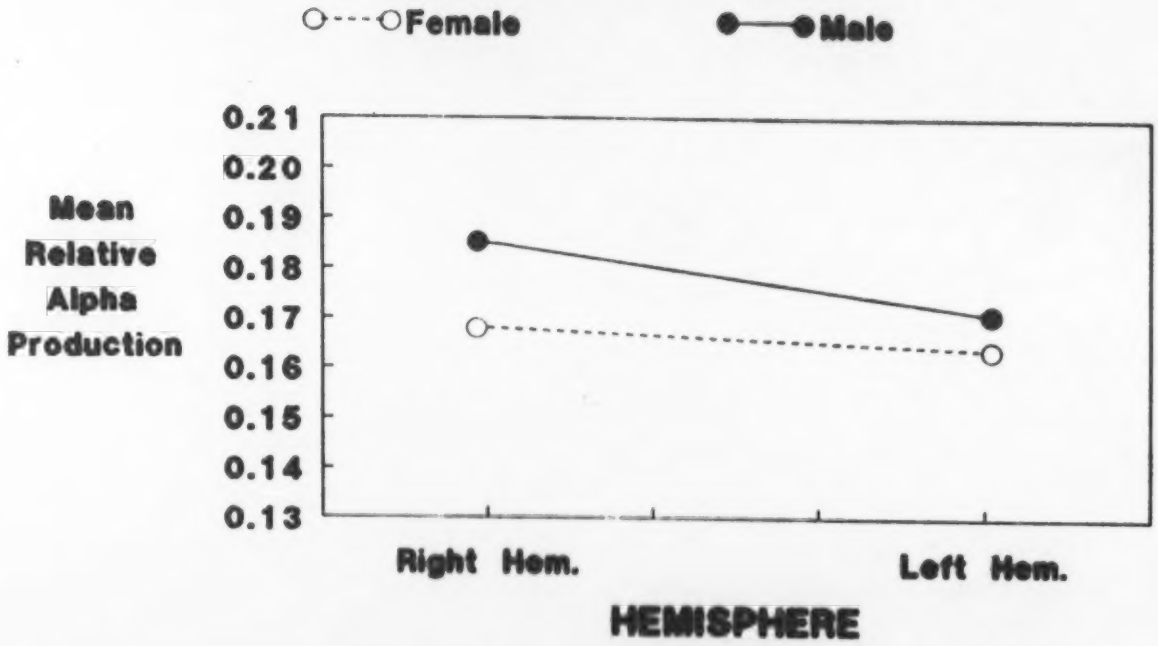
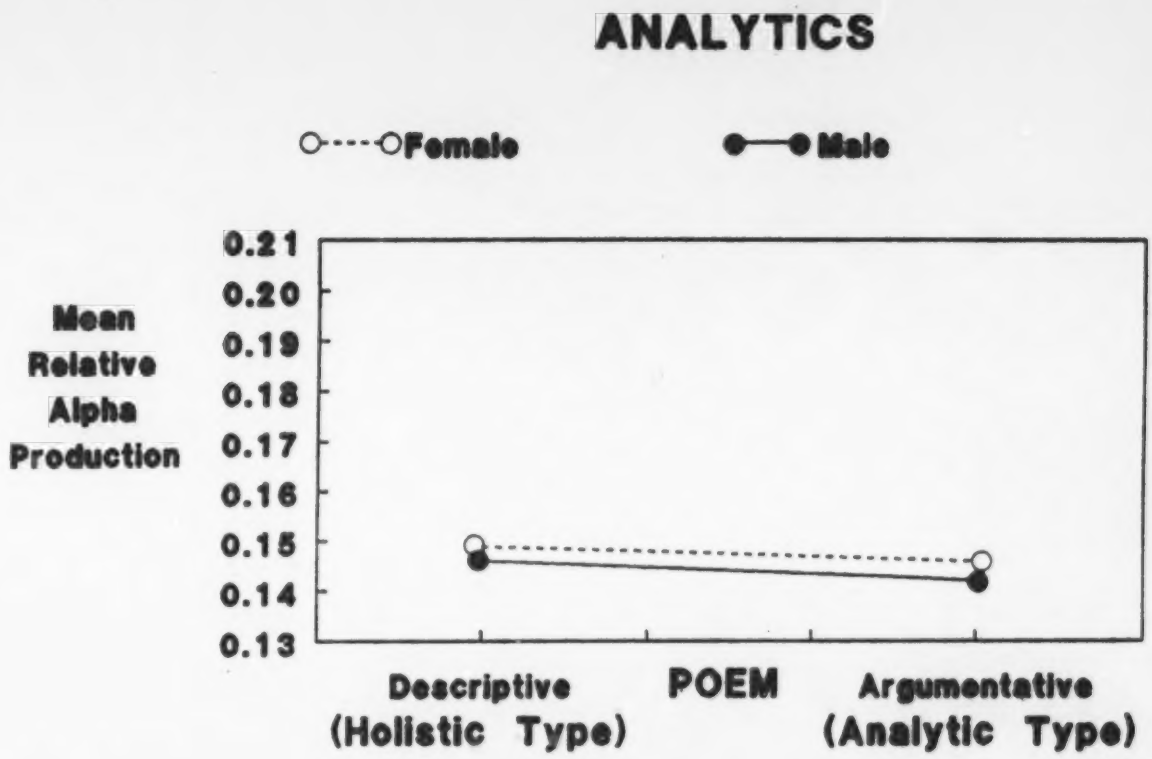


Figure 2 Mean Relative Alpha as a Function of Gender and Hemisphere



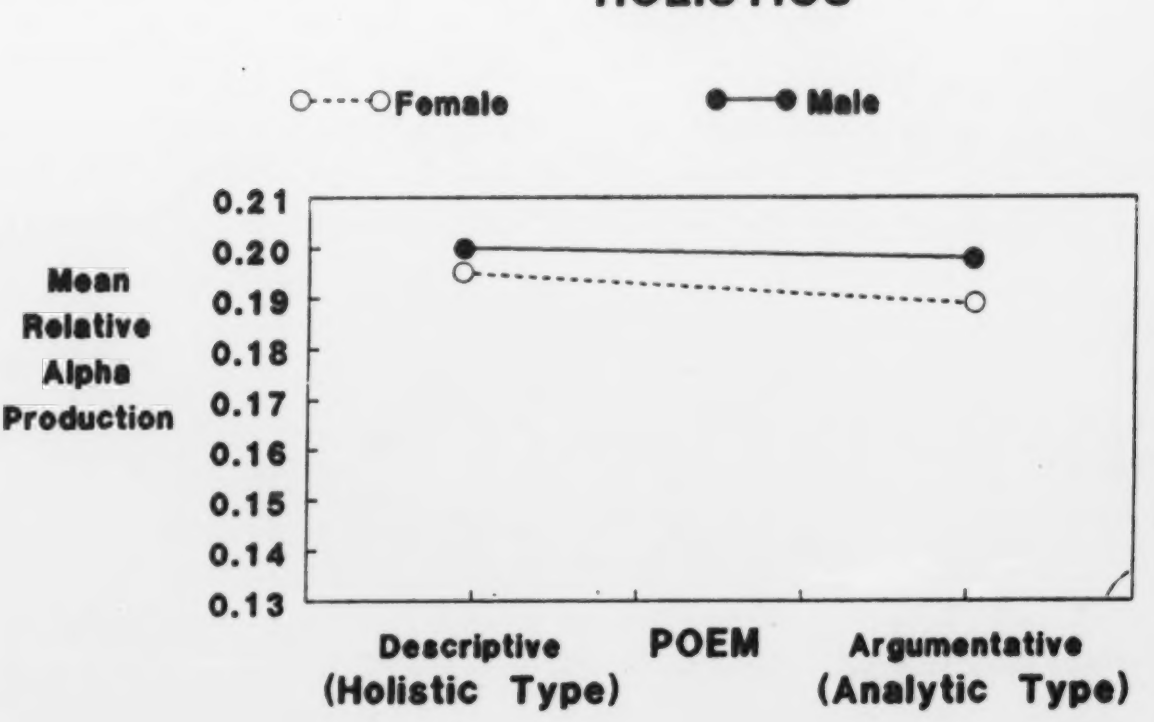


Figure 3 Mean Relative Alpha as a Function of Type Processing, Gender and Poem

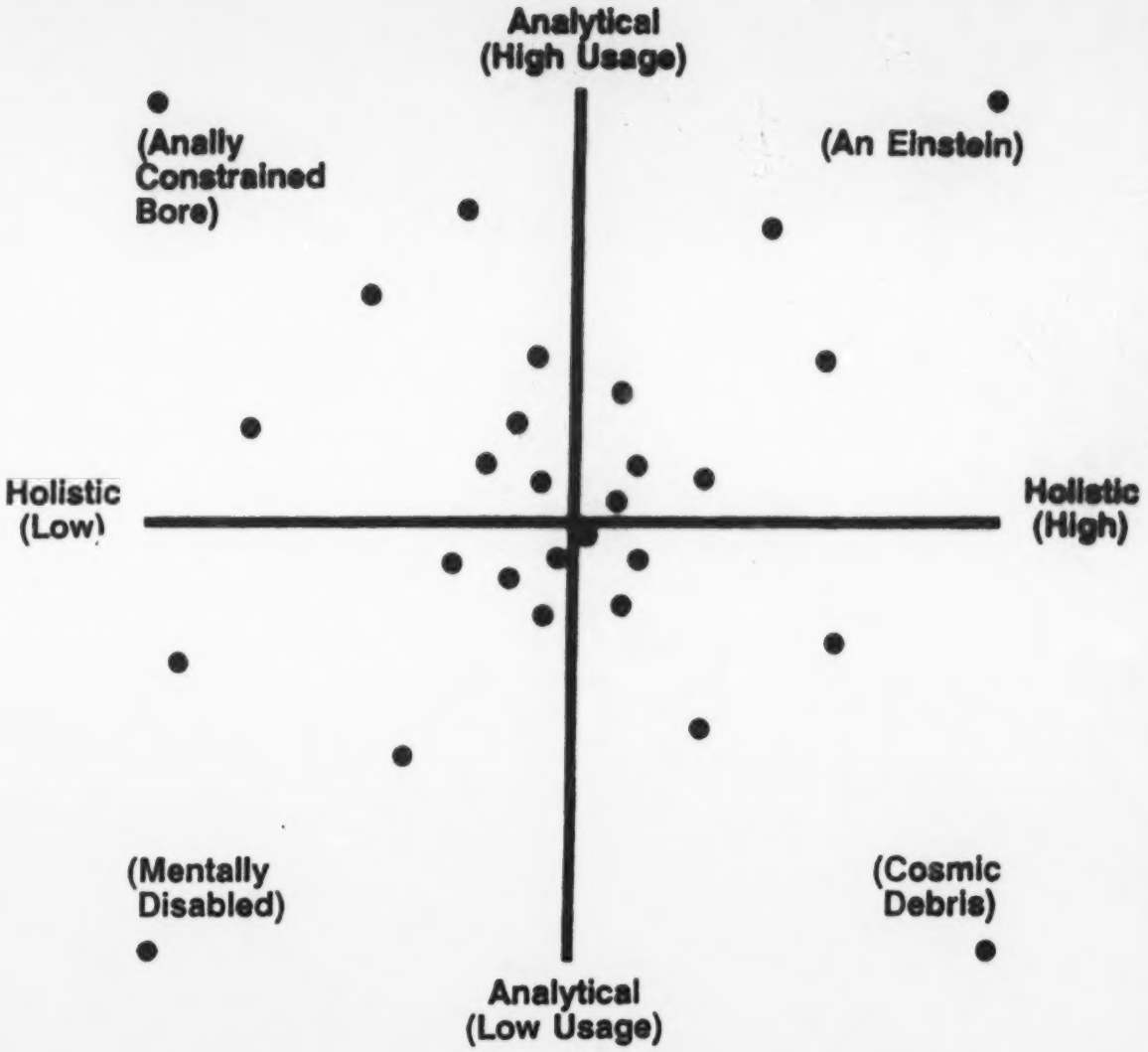


Figure 4 Possible Cognitive Processing Styles

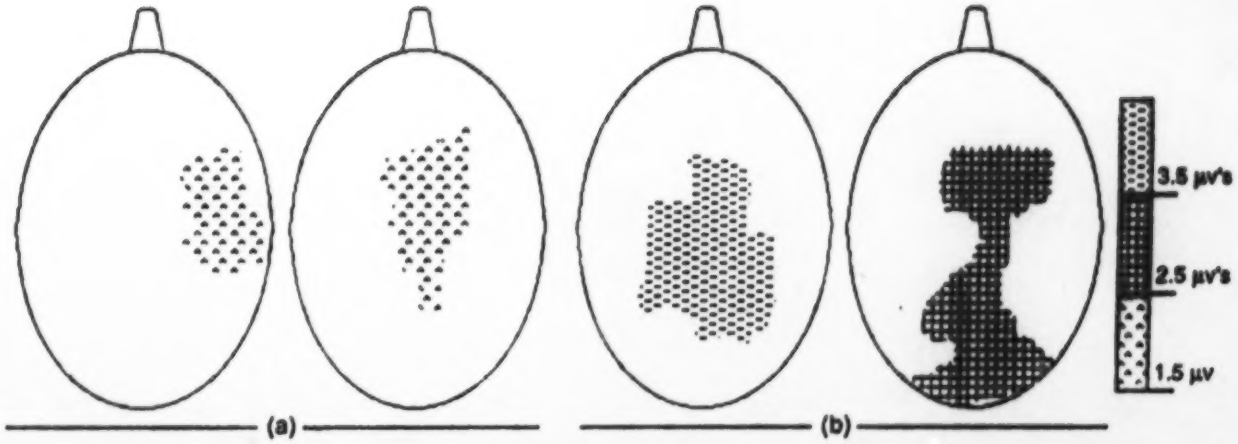


Figure 5 Analytics (a) vs. Holistics (b) cortical distributions of 10 Hz.